Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 12 (2011) 111–116

Engineering Procedia

2011 SREE Conference on Engineering Modeling and Simulation (CEMS 2011)

Study on Distributed Interactive Coal Mine Production Simulation System

Zu-qiang Xiong[1], Jun He, Yan-hui Liu, Lei-lei Zhao, Sheng-quan Zhang

School of Energy Science and Engineering Henan Polytechnic University, Jiao Zuo, 454000,China

Abstract

At present, it exists that the information level of coal mine production and management is low. On the basis of modeling the typical system for mine production, it simulates typical production accidents and establishes databases of mine safety production. Based on the High Level Architecture (abbr. HLA) and Distributed Interactive Simulation (abbr. DIS), it is able to design a set of simulation system for mine safety production, with the function of visualization network and integration. The system is able to model actual production process, educate and train the miners. It can also provide disaster early-warning for mine production. This paper analyses crucial technical problems and technology.

Keywords: HLA; DIS; Coal mine; Simulation system

1. Introduction

The coal is Chinese primary energy. It's also inevitable choice for the Chinese energy strategy development. Safety production is an important guarantee for mining industry sustainable development. But the informatization of coal production plays an important role in safety production [1]. Distributed interactive simulation is connected by many processors (isomerism or isomorphism). The supervisor mode of software and hardware resources makes use of distributed control, so that it can sustain several subsystems collectively and in phase. High level architecture is the forth stage of distributed interactive simulation. The standard of HLA is made by U.S. Defense Modeling and Simulation Office (abbr. DMSO) and has been carried out. It is aimed at promoting interoperability and reusing of the distributed simulation system [2].

2. Overall Frames for System and Developing Simulation Federation

2.1. System Overall Frame

- Designing Overall Frame
  The simulation system for mine safety production is primarily used for visual simulation of mining

[1] Corresponding author: Zu-qiang Xiong, male, doctor, associate professor, involved in mining engineering teaching and research work.
Tel:+86-18639185901;
E-mail address:xzqjzit@163.com.

doi:10.1016/j.proeng.2011.05.019

production. It needs to achieve to input parameters and processing datas. It also needs to realize modeling, rendering scene and interaction. Finally it is able to achieve the goal of visualization display. Therefore the system can be synoptically divided into the following module: date module, modeling module and simulation module.

- Analyzing System Function

The total goal for developing the simulation system is that it is easy to connect each dispersive simulator together by network. So that it is able to provide the informatization and visualization platform for coal mining safety production. The system has the following functions: (1) Man-machine interactive function; (2) Function for realizing special effect; (3).Multi-source dates conversion function [3]; (4) Real-time analysis function; (5) Function for inputting and outputting datum; (6) Knowledge-base for avoiding disaster function.

2.2. Logical Structure of Simulation System Based On HLA

In the simulation system based on HLA, federations are referred to distributed simulation system, which is used to achieve a particular purpose for simulating. Some application programs and components, participated in the system operation, are called federal member. Mutual operation and interaction between federal members is realized by Run Time Infrastructure (abbr. RTI). Logical structure of simulation system based on HLA is shown in figure 1[4].

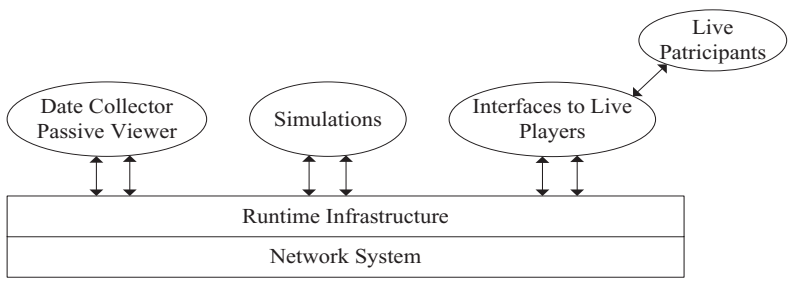

Fig.1 Simulation logical structure

2.3. Designing System Structure

Figure 2 shows the structure of simulation system federation. The system consists of five sections. The first part is three dimensional visualization supporting library, which includes operating system and OSG. It is based on computer graphics hardware and is the hard core of system. The second part on the basis of network hardware supports for distributed interactive simulation based on HLA. The third part is federation model, including scene model and interactive model. The forth part is main executing logic on the basis of OSG platform. The last part holds out stereo, which is based on sound device [5].

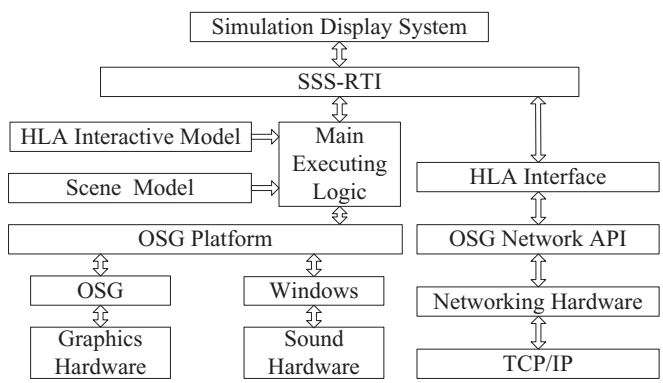

Fig.2 Simulation federation architecture

2.4. Designing Simulation Federation

In the process of federal executing, the information which comes from federal members is accepted by different federations. They don't release object classes and interaction classes, participate in calculating federal model. Moreover joining or quitting federation doesn't essentially influence process and result of federal operation. So that in the stage of designing and developing, object classes and interaction classes are put forward for the simulation federation. Table 1 and table 2 show some of the object classes and interaction classes.

Table 1 Object classes for simulation federation

object class	derived class object	attribute	data type
roadway	development roadway	dposition	position
	preparation roadway	pposition	position
	mining roadway	mposition	position
working face	longwall mining working face	lposition	position
roadway	development roadway	dposition	position

Table 2 Interaction classes for simulation federation

interaction class	derived interaction class	attribute	data type
equipment	production equipment	message	string
	monitoring equipment	message	string
disaster	gas	message	string
	coal dust	message	string
	water	message	string

2.5. Realizing Simulation Program

The whole life cycle of federal executing is managed and maintained [6]. Figure 3 shows the order of calling RTI.

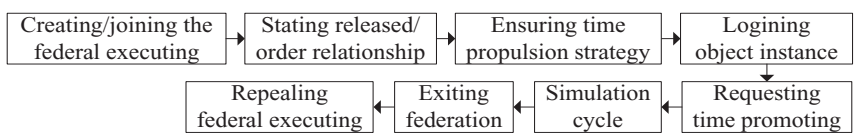

Fig.3 Calling RTI order

3. Key Technologies in Development of System

3.1. Modeling and Optimizing

Three dimensional solid modeling is the important link of constructing simulation environment. The reasonable and reliable 3D models are the basis of implementing the system simulation. Simulation modeling is very different from animation modeling during the system simulation. It is necessary to pay more attention to the behavioral characteristic and motion of models, not the model detail. In order to improve the real-time character of system, it needs to minimize complexity and face number of model with the help of technological means [7]. 3D solid modeling is achieved through 3ds Max. In the interest of fully showing actual things, it needs to make fully use of texture mapping, section lofting, etc. In order to optimize the scene models, it is essential to take advantage of levels of detail.

3.2 Simulating Special-Effect

Simulating special-effect refers to simulating typical disasters, such as gas explosion, mine water inrush, etc.

- Model of fire damp explosion

The property of gas explosion is generally deflagration [8]. But the explosion may become detonation in certain conditions (the conditions of gas concentration distribution, the way and strength of ignition, etc.). After shock wave or detonation wave come into being on account of gas explosion, the flow is assumed one-dimensional steady. One-dimensional spread equation of shock wave or detonation wave is shown by the following formula. It is easy to establish gas explosion model, combined the state equations (p=p(ρ, t)), original condition and boundary conditions.

$$\begin{cases} \rho(D-u)=\rho_0(D-u_0) \\ \rho\left[(D-u)^2+p\right]=\rho_0\left[(D-u_0)^2+p_0\right] \\ \left[e+\dfrac{p}{\rho}+\dfrac{1}{2}(D-u)^2\right]=\left[e_0+\dfrac{p_0}{\rho_0}+\dfrac{1}{2}(D-u_0)^2\right] \end{cases}$$

There: p—Medium pressure in the process of shock wave propagation; p_0—Medium pressure of wave front; ρ—Medium density in the process of shock wave propagation; ρ_0—Medium average density before producing shock wave; u—Medium rate in the process of shock wave propagation; u_0—Medium rate before producing shock wave; T—Medium specific internal energy; T_0—Medium specific internal energy before producing shock wave; D—Speed of explosion shockwave; e—Distribution regularity of T in the time and direction of propagation; e_0—Distribution of medium specific internal energy before producing shock wave.

- Model of water-inrush accident

The model simulates surface water pouring into the roadways through the groundwater channel. When the aquifer is penetrated in the process of drifting tunnel, and cracks connect to the aquifer, which come into being during roof caving of mining face. The physical model of water-inrush accident is shown in figure 4.

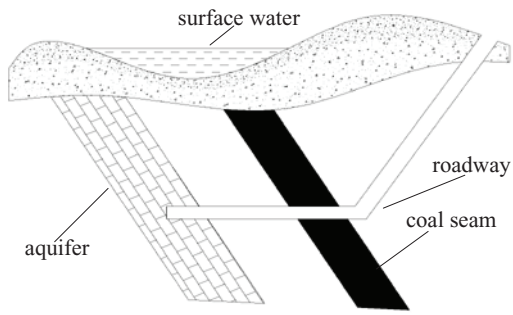

Fig.4 Physical model of water-inrush accident

3.3. Collision Detection

Collision detection is absolutely indispensable function in the great part of three-dimensional simulation platform. Its basic mission is that one object isn't penetrated through or knocked against others. For example, coal shearer can't pass through scraper conveyor, coal lumps drop after hitting the coal winning machine, etc. It plays an important role in enhancing the authenticity and immersive of the simulation environment.

3.4 Driving Simulation Scene

In the process of developing the simulation system, the established simulation scene is displayed in

real time and the scene models are driven and controlled with the help of simulation platform after the solid models and scene models are established. It is easy to produce realistic real-time dynamic visual effect.

The system makes use of Open Scene Graph (abbr. OSG), which is an open source cross platform high performance three dimensional rendering engine. It is widely used in virtual simulation, virtual reality, science and engineering visualization, etc. It makes OpenGL as the underlying platform, compiled by C++. It is able to run on Windows, UNIX/Linux system [9]. Figure 5 shows design sketch for the coal mine production simulation system.

Fig.5 Effect drawing for system running

4. Conclusions

Aim at establishing distributed interactive coal mine production simulation system, this paper discusses the realization processes for distributed interactive simulation, studies on the key technology for establishing federation.

Though the simulation for mine production system, it can meet the need that miners know about the visualization of mining production. Not only does it supply a new feasible way for implementing the education and training of the safety production, but also it can supply an important situ guarantee method for mining safety production.

Acknowledgements

The work reported in this article was supported by the Foundation of NSFC No.50804013.

References

[1] Chen Jianhong, Zhou Keping, etc. Crucial Technology on Constructing the Simulation Imitation Platform of Mine Safety [C]. Proceedings on the Forum of Mining Science and Technology Frontier: pp. 120-125, Nov.2006.

[2] DMSO, High Level Architecture Rules [E], Version l.0, August 15, 1996

[3] Zhao Xiao-liang, Xin xin. Design of Simulation Platform for Submergence of Tidal in Coastal Zone [J]. Computer Engineering, Vol.37 No.40:pp.272-274, Feb. 2011.

[4] Judith S.Dahmann, Richard M.Fujimoto, Richard M.Weatherly. The Department Of Defense High Level Architecture [C]. Proceedings of the 1997 Winter Simulation Conference: pp.142-149, Dec.1997

[5] Zhang Hualei, Wei Sidong, Li Zheyu. Development of Visual Simulation System for Flight Simulation Based on HLA [J]. Control & Automation, Vol .24 No.51:pp.234-236, May.2008.

[6] Frederick Kubl, Richard Weatherly. Creating Computer Simulation Systems an Introduction to High Level Architecture [M], published by Pearson Education, Inc, USA, 2003

[7] Han Jinghua, Huang Xinyuan. Research and Implementation of 3D Landscape Walkthrough System [J]. Journal of Anhui Agri.

Sci, Vol.37 No.32:pp. 16139-16141, Nov. 2009.

[8] Shao Yanmei. Research of Simulation System for Mine Safety Production [J]. Industry and Mine Automation, No.5:pp. 19-21, Oct. 2008.

[9] Wang Ru, Qian Xuelei. Designing and Practicing of OpenSceneGraph Three-dimensional Rendering Engine [M]. Beijing, Tsinghua University Press,2009: pp.3-7.